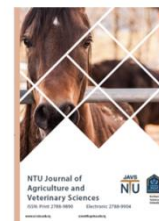




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The Importance of Using Fenugreek (*Trigonella foenum-graecum* L) In Broiler Feeds: A Review

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ABSTRACT

This review emphasizes the significance of fenugreek and its extensive applications in the poultry industry. This information is obtained by providing an explanation of the plant's description, classification, chemical composition, and active elements. Furthermore, it highlights the plant's extensive therapeutic applications, such as its effectiveness as an anti-diabetic, anti-inflammatory, and anti-cancer agent. Additionally, the report examines contemporary methods of injecting eggs with fenugreek extract and analyzes the effects of this practice on the productivity, health, and physiological state of poultry. The promising role of fenugreek in improving poultry health and productivity sheds light on its importance for the poultry industry.



Description of the fenugreek plant

Trigonella foenum-graecum L is the scientific name of fenugreek. It is an old plant that is notable for its extensive recognition attracting considerable attention across many disciplines as well as its designation as "an ancient world crop" [1]. Trigonella is the Latin term for the exact proportion, which is determined by the form of its blossoming blooms, which have a yellowish-white color. Dufenugreek ancient times, it was often known as "Greek hay" and used as a source of nutrition. It was utilized as a fodder crop [2]. The cultivation of this plant is widespread in North Africa, the Mediterranean, India, and Canada as a crop suitable for semi-arid conditions. It has been selectively bred to be a member of the leguminous family [3]. Presently, plants are thriving in many regions including the Indian subcontinent, China, South-East and West Asia, North Africa, Russia, Australia, Western Canada, and Argentina [4]. These regions extensively utilize medicinal and aromatic herbs. Fenugreek has been employed for medical purposes previously [5]. The seeds of Fenugreek contain unique essential components. Researchers have proposed that Fenugreek's physical and chemical qualities have a substantial influence on the food and pharmaceutical industries [6]. The seeds of Fenugreek are bitter because of the presence of saponine, and their unique scent is a result of the flounders and flying oils that are present. The foliage and reproductive cells of Fenugreek can serve as an organic reservoir of antioxidants, antibacterial substances, and antifouling compounds [4]. Researchers conducted a comparative analysis of leaves and seed samples and found a significant presence of ashes, lipids, fibers, carbohydrates, and proteins. Additionally, the samples exhibited a greater energy value, as reported by [8]. Furthermore, the samples shown a wide range of biological features, including antibacterial activity. The preliminary examination of Fenugreek seeds indicated that carbohydrates had the highest proportion (37.79%), followed by fiber (22.48%), protein (20.76%), humidity (8.96%), fat (6.57%), and ash (3.44%), which had the lowest proportion [9].

Table 1. Physiochemical analysis of fenugreek seeds (10)

Components	Concentration % ± standard deviation
(PH acidity)	5.6±0.0075
Humidity (%)	3 ±0.0005
Ash (%)	3 ±0.00
Viscosity (m2Pa/s)	2.8 ±0.0003
Proteins (%)	26.8±0.063
Fats (%)	8.8±0.34
Fiber (%)	5.1±0.00
Pectin (%)	1.9 ±0.00
Sugars (%)	6.7 ±0.0066

Therapeutic significance

Studies indicate that the fenugreek provides a range of health advantages. Galactomannans, a type of soluble fiber present in fenugreek seeds, have the ability to slow down the process of sugar absorption in the digestive tract. This property can be beneficial in managing diabetes and lowefenugreek blood sugar levels. In addition, the presence of an amino acid called 4-hydroxyisoline in fenugreek seeds improves the effectiveness of blood sugar regulation. This amino acid promotes the release of insulin and raises the sensitivity of insulin. Fenugreek seeds possess the ability to augment the milk supply of a breastfeeding mother, lower cholesterol levels, and quadruple fats, in addition to their anti-inflammatory characteristics. The presence of galactomannan, a type of fiber, is the reason behind the reduction in cholesterol absorption in the digestive tract. Moreover, the saponin component found in fenugreek seeds promotes the elimination of cholesterol and inhibits its production in the liver. Studies have demonstrated that ingesting 2.5 grams of fenugreek seed powder twice a day for a duration of three months can result in a decrease in LDL and triglyceride levels in persons who are experiencing elevated amounts of these substances [11]. By virtue of its antimicrobial activity and positive impact on intestinal structure, it improves the performance of poultry animals. Moreover, it possesses the capacity to aid in the prevention of atherosclerosis by diminishing cholesterol levels in avian blood [12]. Several recent studies have shown that including fenugreek with broilers feed improves growth rates and increases weight gains. [13]noticed a 10% increase in growth rate when 1% of fenugreek seeds were added to the meal. The use of a fenugreek to feed quails has the potential to improve the quality of meat by reducing its fat content and increasing its

concentration of essential fatty acids and minerals [14]. Additionally, these fenugreeks play a vital role in the development of obesity, where they have ethical implications when combined with the weight of eggs and yolks, as well as the weight of the crust [15]. Furthermore, contributing to the poultry industry is crucial for promoting growth, improving meat quality, increasing production, and enhancing the body's immune response to diseases. Due to their importance, it is crucial that they do not surpass 5% of the feed [16].

Table 2. Concentration of trace elements of fenugreek plant [10]

Elements	Concentration $\mu\text{g/g}$
Potassium (K)	10605 \pm 555
Iron (Fe)	91 \pm 6
Lead (Pb)	0.4 \pm 0.00
Zinc (Zn)	30.9 \pm 1.5
Cadmium (Cd)	0.03 \pm 0.002
Calcium (Ca)	1445 \pm 68
Chromium (Cr)	0.2 \pm 0.007
Magnesium (Mg)	1229 \pm 88
Nickel (Ni)	1.3 \pm 0.90

Advantages of Fenugreek

Scientific research has confirmed that fenugreek provides several benefits, including as its application in traditional medicine as an anti-diabetic, antimicrobial, and anorexigenic (appetite-suppressing) substance. Over the past few decades, researchers have conducted countless experiments on animals and humans to study the substances that can be good for plant growth, such as capsules that reduce sugar and cholesterol levels. The main factor for these anti-diabetic qualities and the decrease in cholesterol levels is the existence of dietary fibers, which hold promise for various food uses [17]. Many researchers have been motivated to study and apply effective natural treatments due to the increasing occurrence and advancement of many diseases that impact both humans and animals. An essential herb with numerous biologically active compounds has gained recognition as a medicinal plant for its effectiveness in treating various diseases such as cancer, elevated levels of cholesterol, diabetes, and infections. Due to its therapeutic characteristics and the possibility of extracting it as a powder or extract from different areas of fenugreek plant, it has potential for medicinal usage [18]. Fenugreek exhibits therapeutic efficacy by possessing antibiotic, antioxidant, and anti-cancer properties. It also has the capability to regulate high blood sugar levels in diabetic patients. Additionally, Fenugreek contains various bioactive compounds

such as Flavonoids, quilloides, fibers, and fatty acids [19]. In addition, fenugreek seeds contain about 100 plant compounds, including as carbohydrates, quilloides, phenolic acids, and flavonoids. Fenugreek extracter and its biologically active chemicals shown remarkable anti-diabetic and antitoxin properties in both animal and human studies [20]. Throughout history, Fenugreek has been well acknowledged as a highly potent medicinal herb. In addition, it has nutritional value. Its antibacterial properties and positive impact on the bird's health and digestive system make it a plant that promotes the improvement of chicken growth performance [21]. Furthermore, its lush foliage and seeds are utilized for a multitude of uses. The inclusion of fenugreek in the broiler feed has been found to improve productivity, decrease feed expenses, and boost profits [22]. Additionally, the use of fenugreek seeds has been shown to enhance the vascular performance of the laying hens' ancestors by improving blood quality [23]. The dietary fiber content of fenugreek seeds contributes to the overall health of the digestive system [24]. Additionally, it is reducing the level of blood claustrophobia. [25]. The seeds of Fenugreek are widely utilized in the management of disorders, human nutrition, and the utilization of sulfate for its anti-diabetic, anti-oxidant, and anti-cancer properties [26].

Table 3. Approximate analysis of fenugreek seed powder [50]

Nutrients	%
Dry matter	90.67
Crude protein	30.82
Raw fiber	14.80
Ether extract	3.42
ash	4.50

training. Moreover, it promotes rapid and effective absorption of injectable medications, improves efficiency, and results in reduced educational costs [36] [37]. It is crucial to use personal protection equipment and use syringes with sterile needles. The maximum allowable volume of the injected substance is 0.4 ml, and each individual injection should not exceed 0.1 ml [6]. Enhancing the egg with various nutrients facilitates the development of the fetus, leading to the production of healthier chicks and a successful hatching process [38]. The egg injection technique is a procedure employed to enhance fetal growth and bolster its immune system. Injecting substances such as carbohydrates, fatty acids, vitamins, and hormones into the egg can improve the immune system of the developing fetus

and newly hatched chicks [39]. Administering fat-soluble vitamins, like vitamin D3, to eggs affects the hatching and post-hatching performance and improves the hatching rate [40]. The egg is composed of 74% water, 11.8% fat, 12.8% proteins, and trace amounts of metals and carbohydrates, estimated at 1.9%. The chemical composition of the egg renders it a fundamental and comprehensive source of nourishment for the developing chicken embryo. In addition, the injection process of the egg can supply the embryo with essential nutrients that have the potential to enhance its growth, development, and ability to resist diseases [41].

Broilers industry

The rapid and exponential increase in the world's population has made it imperative to create more robust and reliable food supply systems. Poultry meat has become a highly efficient, generally recognized, and popular protein source for many years [42]. [43] reported that it has the highest global consumption rate. Although hens have been subjected to crossbreeding since the prehistoric era, the practice of breeding meat chickens is a relatively recent advancement that emerged in the past century. Chickens possess a remarkable ability to adapt, allowing them to flourish in many breeding environments, including those that are particularly demanding [44]. The body weight of meat poultry has rapid growth, with a growth rate of 3 to 4 times within the initial week. The digestive system undergoes a noticeable alteration after experiencing rapid enlargement [45]. Poultry meat is commonly acknowledged as a nutritionally beneficial dietary option, and the costs connected with its production are comparatively low [46]. The United States became the top global producer of poultry meat in 2020, accounting for 40.5% of the total global production. China and Brazil ranked second and third, respectively, in terms of output volume, according to the [47]

Impact of Fenugreek on production characteristics

Measurement of an individual's present body weight and the following increase in weight over a period of time.

The study conducted by [48] investigated the impact of adding nutritional supplements to the broilers feed at varying ratios (0.5%, 1.5%, and 1.5%) with fenugreek seeds as a growth stimulant. The findings of this study revealed that there was no statistically significant disparity in the baseline body weight between the groups being examined. However, there was a notable variation in the final body weight

($P < 0.005$), with the highest increase observed in the third group. In a study conducted by [49], the inclusion of fenugreek seed powder at concentrations of 1%, 2%, and 3% had a significant impact on the groups where the powder was added at concentrations of 2% and 3%, resulting in more pronounced effects on mortality compared to the control group. [50] discovered that incorporating fenugreek seed powder into broilers feed at a concentration of 1% led to substantial weight gain in the subjects' bodies at 6 and 8 weeks of age, as well as throughout the entire educational period (0-8 weeks). The smallest weight gain occurred between weeks 6 and 8, and this pattern continued when Fenugreek seed powder was administered at a higher dosage of 1.5%. A study conducted by [51] found that incorporating fenugreek seed powder into broilers feed at different ratios did not lead to any noteworthy changes in the individuals' body weight. Nevertheless, there was a significant disparity in the rate of weight increase between the groups that were administered fenugreek powder at 0.5% and 1%. A study conducted by [52] found that adding a fenugreek to the broilers feed at different proportions, along with a 6-week educational program, had a significant effect on weight gain, particularly at 2.5. In their study, [53] found that adding Fenugreek extract to the broilers feed at different quantities (0.50, 100, 200, 400, and 800 mg/kg) in the diet led to a substantial and observable increase in weight gain. [54] found that incorporating fenugreek seed powder into broilers feed at varying dosages significantly affected the rate of weight increase, as assessed in grams. In [55] found that adding varying amounts of fenugreek powder to kalonji (black cumin seed) led to improved body weight and greater productivity. [56] conducted a study where broilers feed were divided into four groups, one of which served as the control group. Varying concentrations of fenugreek seed powder were administered to each group, with one group receiving 0.7% and another group receiving 1.4%. The duration of the trial was 42 days. The latest batch was added to fenugreek powder, resulting in a 2.8% rise. The researcher noted that adding fenugreek to the broilers feed in different amounts resulted in positive effects on the weight gain and overall body weight of the broilers.

Food conversion factor and feed consumption

There was no discernible difference in the food conversion coefficient while varying the amounts of fenugreek, according to [48]. However, it was found that adding 0.5%, 1%, and 1.5% of fenugreek resulted in an increase in feed consumption, while the control group, which did not receive fenugreek seeds, had lower feed consumption. In a study by [49], it was observed that the control group had the highest food conversion efficiency, while the chicks that received additional food did not show any significant difference compared to those fed with

fenugreek powder. The research conducted by [50] revealed that incorporating fenugreek seed powder into the broilers feed throughout the entire educational period had a significant positive effect on the food conversion coefficient. In addition, the inclusion of 1.5% fenugreek seed powder in broilers feed resulted in a reduction in feed consumption levels within 8 weeks of the entire study period, compared to the group that got a 0.5% addition. [51] discovered that including fenugreek seed powder in different amounts had a noteworthy effect on the second treatment, particularly when administered at a concentration of 0.5%. Nevertheless, including varying amounts of fenugreek seed powder into the broilers feed did not yield any noticeable disparity in feed intake. A recent study has shown that including fenugreek seeds in the diet of broilers leads to a reduction in the food conversion coefficient [25]. Using a fenugreek to feed broilers leads to a significant improvement of around 12% in the food conversion coefficient. The improvement and decline can be attributed to the existence of biologically active substances within the structure that aid in the absorption of nutrients and dietary representations. The decrease in food consumption is also influenced by bioactive chemicals found in fenugreek [14]. In a study conducted by [49], it was found that adding fenugreek seed powder to the broilers feed at different levels (1%, 2%, and 3%) resulted in the highest food conversion efficiency in the group where fenugreek seed powder was introduced at a concentration of 3%. [12] found that adding fenugreek seeds to the fattening chicken accelerator at a concentration of 5 mg/kg feed increased the food conversion coefficient. Similarly, incorporating 3 mg/kg of fenugreek seed powder into the feed had a significant effect on the food conversion coefficient after 42 days. The inclusion of this substance was similarly linked to the proliferation and maturation of the intestines in broilers [57]. In a previous study conducted by Mangrulle et al. in 2022, it was found that adding fenugreek as an additional herb to chicken feeds improves feed consumption.

The effects of adding fenugreek seed powder to blood samples and the chemical properties of the blood serum.

Toson and Abd Ellatif (2021) conducted a recent study which found that adding 1% fenugreek seed powder to broilers feed led to a noteworthy enhancement in nutritional content. More precisely, there was a rise in the overall protein concentration and a decrease in the levels of cholesterol in the blood serum. Paneru et al., 2022 conducted a study showing that adding 10 grams of fenugreek seeds to the broilers feed, there was an increase in lymph and variable cells. [51] did a study to investigate the effects of food fenugreek seed powder on the performance of broilers feed. The study investigated two different rates of 0.5% and 1.5%. The findings

indicated that the addition of the powder, at either rate, did not have a significant impact on the size of the cells, the rate of pellets, or the concentration rate of the pellets. Nevertheless, the addition of 0.5% of the powder resulted in a notable disparity in the white blood cell count, while the inclusion of 1.5% of the powder led to a reduction in the cholesterol ratio. A study conducted by [58] found that including fenugreek seeds into poultry feed led to a decrease in blood cholesterol levels. This discovery has significant ramifications for the prevention of vascular disorders. [59] found that adding Moranga Olivera extract to chicken feed in identical proportions led to a notable increase in both blood protein levels and cloccos levels. [60] discovered that Fenugreek had a noteworthy effect on augmenting the quantity of red blood cells, the concentration of hemoglobin, and total protein levels ($p > 0.01$) in individuals who were 6 weeks old. In addition, it resulted in a significant decrease in cholesterol and blood sugar levels ($p > 0.01$) in the blood serum. [61] found that feeding birds with feed containing different amounts of fenugreek seed powder resulted in reduced levels of cloccos and cholesterol in the bird blood plasma, compared to the control treatment where no fenugreek was supplied. A study conducted by [17] demonstrated that Fenugreek had a significant effect on the ratio of cholesterol and LDL fatty protein in the rats to which it was delivered. [17] found through a series of animal experiments that Fenugreek effectively reduced blood cholesterol levels.

References

- [1] Faisal, Z., Irfan, R., Akram, N., Manzoor, H. M. I., Aabdi, M. A., Anwar, M. J., ... & Desta, D. T. (2024). The multifaceted potential of fenugreek seeds: From health benefits to food and nanotechnology applications. *Food Science & Nutrition*. <https://doi.org/10.1002/fsn3.3959>
- [2] Vanghele, N., MATAACHE, A., PETRE, A., STANCIU, M., & MIHALACHE, D. J. A. o. t. U. o. C.-A., Montanology, Cadastre Series. (2021). Cultivation technology and benefits of fenugreek. *50(2)*, 558-563.
- [3] Salarbashi, D., Bazeli, J., & Fahmideh-Rad, E. J. I. j. o. b. m. (2019). Fenugreek seed gum: Biological properties, chemical modifications, and structural analysis—A review. *138*, 386-393. <https://doi.org/10.1016/j.ijbiomac.2019.07.006>
- [4] Ghanghas, N., Prabhakar, P. K., Sharma, S., & Mukilan, M. T. (2021). Microfluidization of fenugreek (*Trigonella foenum graecum*) seed protein concentrate: Effects on functional, rheological, thermal and microstructural properties. *LWT*, *149*, 111830. <https://doi.org/10.1016/j.lwt.2021.111830>
- [5] Mamatha, N.C., Panyam, K.R. (2021). Agronomic Practices in Fenugreek. In: Naeem, M., Aftab, T., Khan, M.M.A. (eds) Fenugreek. Springer, Singapore 83-97. https://doi.org/10.1007/978-981-16-1197-1_5

- [6] Yao, D., Zhang, B., Zhu, J., Zhang, Q., Hu, Y., Wang, S., ... & Xiao, J. (2020). Advances on application of fenugreek seeds as functional foods: Pharmacology, clinical application, products, patents and market. *Critical reviews in food science and nutrition*, 60(14), 2342-2352. <https://doi.org/10.1080/10408398.2019.1635567>
- [7] Salam, S. G. A., Rashed, M. M., Ibrahim, N. A., Rahim, E. A. A., Aly, T. A., & Al-Farga, A. (2023). Phytochemical screening and in-vitro biological properties of unprocessed and household processed fenugreek (*Trigonella foenum-graecum* Linn.) seeds and leaves. *Scientific Reports*, 13(1), 7032. | <https://doi.org/10.1038/s41598-023-31888-y>
- [8] Bakhtiar, Z., Hassandokht, M., Naghavi, M. R., & Mirjalili, M. H. (2024). Variability in proximate composition, phytochemical traits and antioxidant properties of Iranian agro-ecotypic populations of fenugreek (*Trigonella foenum-graecum* L.). *Scientific Reports*, 14(1), 87. | <https://doi.org/10.1038/s41598-023-50699-9>
- [9] Raji-Idowu, F. O. O. (2023). Antibacterial Activities of Fenugreek Oil and Seed Extracts on Selected Pathogenic Bacteria and Proximate Composition of Fenugreek Seed. *Nigerian Journal of Microbiology*. *Nigerian Journal of Microbiology*, 37(2): 6729 – 6735
- [10] Liu, T. (2024). Fenugreek: Benefits, Dosage, Side Effects and Risks.
- [11] Paneru, D., Tellez-Isaias, G., Romano, N., Lohakare, G., Bottje, W. G., & Lohakare, J. (2022). Effect of graded levels of fenugreek (*Trigonella foenum-graecum* L.) seeds on the growth performance, hematological parameters, and intestinal histomorphology of broiler chickens. *Veterinary Sciences*, 9(5), 207. <https://doi.org/10.3390/vetsci9050207>
- [12] Patel, S., Atta Awad E. (2018). "Effects of fenugreek seeds on meat quality and fatty acid profiles in broiler chickens." *Meat Science*, 142, 154-159. doi: 10.1093/jas/skaa300
- [13] Hamdia, M. S., Al-Hajo, N. N., Al Mjbel, A. A. S., & Abdulwahid, A. S. (2021). IMPACT OF COMBINATION OF FENUGREEK SEEDS (*Nigella sativa*), LAURELS LEAVE (*Laurus nobilis*) AND VITAMIN C ON SOME EGG QUALITY CHARACTERISTICS OF QUAIL: IMPACT OF COMBINATION OF FENUGREEK SEEDS (*Nigella sativa*), LAURELS LEAVE (*Laurus nobilis*) AND VITAMIN C ON SOME EGG QUALITY CHARACTERISTICS OF QUAIL. *Iraqi Journal of Market Research and Consumer Protection*, 13(2), 56-67. <http://dx.doi.org/10.28936/jmracpc13.2.2021.5>
- [14] Shahwan al-Hamdani, H. M., Ahmed, S. H., Twij, M., & Khadadat, S. (2020). EFFECT OF ANIMAL FEED SUPPLEMENTATION WITH DIFFERENT CONCENTRATIONS OF FENUGREEK SEEDS (*Trigonella foenum-graecum*) ON ANIMAL PRODUCTION AND MICROBIAL CHICKEN MEAT. *Iraq Journal of Market Research & Consumer Protection/Al-Mağalla' al-'Irāqīyyā' li-Buḥū' al-Sūq wa-Ḥimāyā' al-Mustahlik*, 12(2).
- [15] Srinivasan, K. (2019). Fenugreek (*Trigonella foenum-graecum* L.) seeds used as functional food supplements to derive diverse health benefits. In *Nonvitamin and nonmineral nutritional supplements* (pp. 217-221): Elsevier. <https://doi.org/10.1016/B978-0-12-812491-8.00031-X>
- [16] Syed, Q. A., Rashid, Z., Ahmad, M. H., Shukat, R., Ishaq, A., Muhammad, N., & Rahman, H. U. U. (2020). Nutritional and therapeutic properties of fenugreek (*Trigonella foenum-graecum*): a review. *International Journal of Food Properties*, 23(1), 1777-1791. <https://doi.org/10.1080/10942912.2020.1825482>
- [17] Ruwali, P., Pandey, N., Jindal, K., & Singh, R. V. (2022). Fenugreek (*Trigonella foenum-graecum*): Nutraceutical values, phytochemical, ethnomedicinal and pharmacological overview. *South African Journal of Botany*, 151, 423-431. <https://doi.org/10.1016/j.sajb.2022.04.014>
- [18] Yao, D., Zhang, B., Zhu, J., Zhang, Q., Hu, Y., Wang, S., ... & Xiao, J. (2020). Advances on application of fenugreek seeds as functional foods: Pharmacology, clinical application, products, patents and market. *Critical reviews in food science and nutrition*, 60(14), 2342-2352. <https://doi.org/10.1080/10408398.2019.1635567>
- [19] Murlidhar, M., Goswami, T. J. J. o. F. P., & Technology. (2012). A review on the functional properties, nutritional content, medicinal utilization and potential application of fenugreek. 3(9). http://www.omicsonline.org/2157-7110/2157-7110-abstract.php?abstract_id=8944
- [20] Toaha, S. M., Mollah, B. R., Ahammad, M. U. J. R. i. A. L., & Fisheries. (2016). Use of dietary fenugreek (*Trigonella foenum-graecum* L.) seed for the production of safe broiler lean meat. 3(2), 305-314.
- [21] Smith, J., Vadalasetty, K.P. (2020). "Impact of fenugreek fiber on digestive health." *Journal of Nutrition and Health*. 102 (1): e364–e373. doi:10.1111/jpn.12754
- [22] Johnson, L., & Patel, S. (2021). "Fenugreek and blood sugar regulation: A clinical review." *Diabetes*
- [23] Srivastava, A., Singh, Z., Verma, V., & Choedon, T. (2022). Potential health benefits of fenugreek with multiple pharmacological properties. In *Research Anthology on Recent Advancements in Ethnopharmacology and Nutraceuticals* (pp. 672-687). IGI Global. DOI: 10.4018/978-1-6684-3546-5.ch034
- [24] Uni, Z., & Ferket, R. J. W. s. P. S. J. (2004). Methods for early nutrition and their potential. 60(1), 101-111. DOI: <https://doi.org/10.1079/WPS20038>
- [25] Al-Shamery, N. J., & Al-Shuhaib, M. B. S. (2015). Effect of in ovo injection of various nutrients on the hatchability, mortality ratio and weight of the broiler

- chickens. *IOSR Journal of Agriculture and Veterinary Science*, 8(2), 30-33. DOI: 10.9790/2380-08123033
- [26]Schaal, T. P. (2008). The Effects of in ovo feeding of fatty acids and antioxidants on broiler chicken hatchability and chick tissue lipids. https://ir.library.oregonstate.edu/concern/honors_college_theses/9c67wp79f
- [27]Dunachie, J. F., & Fletcher, W. W. (1969). An investigation of the toxicity of insecticides to birds' eggs using the egg-injection technique. *Annals of applied biology*, 64(3), 409-423. <https://doi.org/10.1111/j.1744-7348.1969.tb02890.x>
- [28]Surai, P. F. (2017). Antioxidant defences: Food for thoughts. *EC Nutrition*, 10(2), 65-66.
- [29]Aberbour, A., Touazi, L., Benberkane, A., Aissanou, S., Sherasiya, A., Iguer-Ouada, M., ... & Moula, N. (2023). The effect of in ovo administration of rosemary essential oil on hatchability, relative hatching weight, and embryo mortality rate in Japanese quail (*Coturnix coturnix japonica*). *Animals*, 13(7), 1217. <https://doi.org/10.3390/ani13071217>
- [30]Oliveira, G. d. S., McManus, C., Salgado, C. B., & Dos Santos, V. M. J. V. S. (2023). Bibliographical Mapping of Research into the Relationship between In Ovo Injection Practice and Hatchability in Poultry. 10(4), 296. <https://doi.org/10.3390/vetsci10040296>
- [31]Ebrahimi, M. R., Ahangari, Y. J., Zamiri, M. J., Akhlaghi, A., & Atashi, H. (2012). Does preincubational in ovo injection of buffers or antioxidants improve the quality and hatchability in long-term stored eggs?. *Poultry science*, 91(11), 2970-2976. <https://doi.org/10.3382/ps.2012-02246>
- [32]Zhao, M., Li, J., Shi, Q., Shan, H., Liu, L., Geng, T., ... & Gong, D. (2023). The effects of in ovo feeding of selenized glucose on selenium concentration and antioxidant capacity of breast muscle in neonatal broilers. *Biological Trace Element Research*, 201(12), 5764-5773. <https://doi.org/10.1007/s12011-023-03611-5>
- [33]Gupta, V., Ncho, C. M., Goel, A., Jeong, C. M., & Choi, Y. H. (2022). Effects of in ovo injection of α -ketoglutaric acid on hatchability, growth, plasma metabolites, and antioxidant status of broilers. *Antioxidants*, 11(11), 2102. <https://doi.org/10.3390/antiox11112102>
- [34]Shebl, M. K., & Hassan, M. I. (2018). The effect of in-ovo injection of some nutrients on productive performance and some physiological traits of Hubbard broiler chicks. *Egyptian Poultry Science Journal*, 38(4), 923-941. <http://www.epsjournals.ekb.eg/>
- [35]Fatemi, S. A., Elliott, K. E. C., Bello, A., Durojaye, O. A., Zhang, H., & Peebles, E. D. (2020). Effects of source and level of in ovo-injected vitamin D3 on the hatchability and serum 25-hydroxycholecalciferol concentrations of Ross 708 broilers. *Poultry science*, 99(8), 3877-3884. <https://doi.org/10.1016/j.psj.2020.04.030>
- [36]Zhong, Z., Yu, Y., Jin, S., & Pan, J. (2018). Effects of mixing eggs of different initial incubation time on the hatching pattern, chick embryonic development and post-hatch performance. *PeerJ*, 6, e4634. <https://doi.org/10.7717/peerj.4634>.
- [37]Khomayezi, R., & Adewole, D. (2022). Probiotics, prebiotics, and synbiotics: an overview of their delivery routes and effects on growth and health of broiler chickens. *World's Poultry Science Journal*, 78(1), 57-81. <https://doi.org/10.1080/00439339.2022.1988804>
- [38]Siegel, P. B. (2014). Evolution of the modern broiler and feed efficiency. *Annu. Rev. Anim. Biosci.*, 2(1), 375-385. <https://doi.org/10.1146/annurev-animal-022513-114132>
- [39]Abd El-Azeem, N. A., Madkour, M., Hashem, N. M., & Alagawany, M. (2024). Early nutrition as a tool to improve the productive performance of broiler chickens. *World's Poultry Science Journal*, 80(1), 171-185. <https://doi.org/10.1080/00439339.2023.2262443>
- [40]Ravindran, V. (2013). Poultry feed availability and nutrition in developing countries. *Poultry development review*, 2(11), 60-63.
- [41]FAO. FAO Statistics. Available online: <https://www.fao.org/faostat/en/#data/QCL/visualize> (accessed on 1 May 2022)
- [42]Ali, A. H., Yeasmin, T., Mohamed, Y. A., Mohamud, A. I., & Mishra, P. (2021). Evaluation of dietary supplementation of fenugreek seed (*Trigonella foenum-graecum* L.) as a growth promoter in broiler diet and its impacts on growth performance, carcass quality and cost effectiveness. *Journal of Istanbul Veterinary Sciences*, 5(1), 6-12.: <https://doi.org/10.30704/http-www-jivs-net.815835>
- [43]Yassin, M., Nurfeta, A., & Banerjee, S. (2020). The effect of supplementing fenugreek (*Trigonella foenum-graecum* L.) seed powder on growth performance, carcass characteristics and meat quality of Cobb 500 broilers reared on conventional ration. *Ethiopian Journal of Agricultural Sciences*, 30(3), 129-142.
- [44]Toson, E. M., & Abd Ellatif, M. A. (2021). EFFECT OF USING FENUGREEK SEEDS POWDER AS A FEED ADDITIVE IN BROILER CHICKS DIET ON GROWTH PERFORMANCE AND SOME METABOLIC RESPONSES. *Egyptian Poultry Science Journal*, 41(1), 31-43. [10.21608/epsj.2021.159929](https://doi.org/10.21608/epsj.2021.159929)
- [45]Hussein, Y. A., Zomrawi, W. B., Fadol, A. M., Algam, T. A., Osman, R. H., & Abdalhag, M. A. (2023). Effect of Dietary Fenugreek Seed Powder on Broiler Chicks Performance. *Al-Qadisiyah Journal For Agriculture Sciences*, 13(1). : DOI: 10.33794/qjas.2023.136919.1103
- [46]Kumar, P., Walia, R., Punia, S., Sihag, S., Kumar, S., & Sihag, Z. S. (2021). Effect of dietary supplementation of fenugreek seed powder on growth, carcass traits and hematological parameters in broiler chickens. DOI: <https://doi.org/10.22271/j.ento.2021.v9.i2d.8487>

- [47]Huang, H., Wang, X., Yang, L., He, W., Meng, T., Zheng, K., . . . Liu, C. J. F. i. V. S. (2022). The Effects of Fenugreek Extract on Growth Performance, Serum Biochemical Indexes, Immunity and NF- κ B Signaling Pathway in Broiler. 9, 882754. <https://doi.org/10.3389/fvets.2022.882754>
- [48]D CHANDANKAR, S. O. N. A. L. I., Palod, J., SINGH, V., & Singh, S. K. (2023). Efficacy of Dietary Fenugreek and Kalonji Seed Powder on Carcass Traits of Guinea Fowls. *Indian Journal of Animal Production and Management*, 37(2), 188-193. <https://doi.org/10.48165/ijapm.2023.37.2.16>
- [49]Rahimian, Y., Akbari, S. M., Karami, M., & Fafghani, M. J. B. s. J. o. B. (2018). Effect of different levels of Fenugreek powder supplementation on performance, Influenza, Sheep red blood cell, New Castle diseases anti-body titer and intestinal microbial flora on Cobb 500 broiler chicks. 9(18). DOI: 10.7904/2068-4738-IX(19)-29
- [50]Mangrule, P., & Kamble, S. (2022). Effect of antibiotics vis-a-vis fenugreek seed powder (*Trigonella foenum-graecum* L.) on growth performance and feed conversion efficiency of broilers. 2022, Vol. 40, No. 3/4, 435-442 ref. 20 ref.
- [51]Abd El Latif, M. A. (2022). EFFECTIVENESS OF CERTAIN NATURAL FEED SUPPLEMENTS ON PRODUCTIVE PERFORMANCE, NUTRIENTS DIGESTION COEFFICIENT, CARCASS CHARACTERISTICS, AND SOME BLOOD PARAMETERS OF BROILER CHICKS SHORT TITLE: EFFECT OF NATURAL FEED ADDITIVES ON BROILER. *Egyptian Poultry Science Journal*, 42(1), 77-93. [10.21608/EPSJ.2022.225224](https://doi.org/10.21608/EPSJ.2022.225224)
- [52]Srinivasan, K. (2006). Fenugreek (*Trigonella foenum-graecum*): A review of health beneficial physiological effects. *Food reviews international*, 22(2), 203-224. <https://doi.org/10.1080/87559120600586315>